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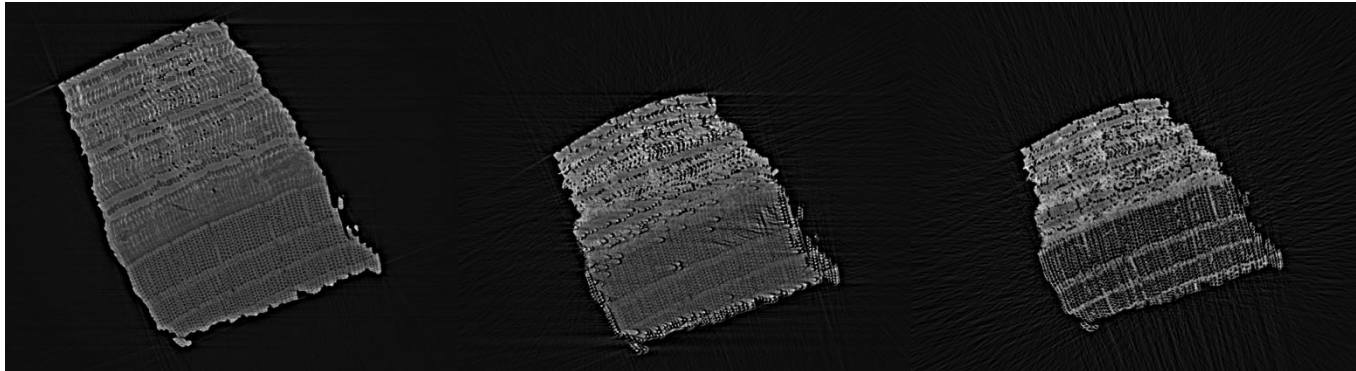
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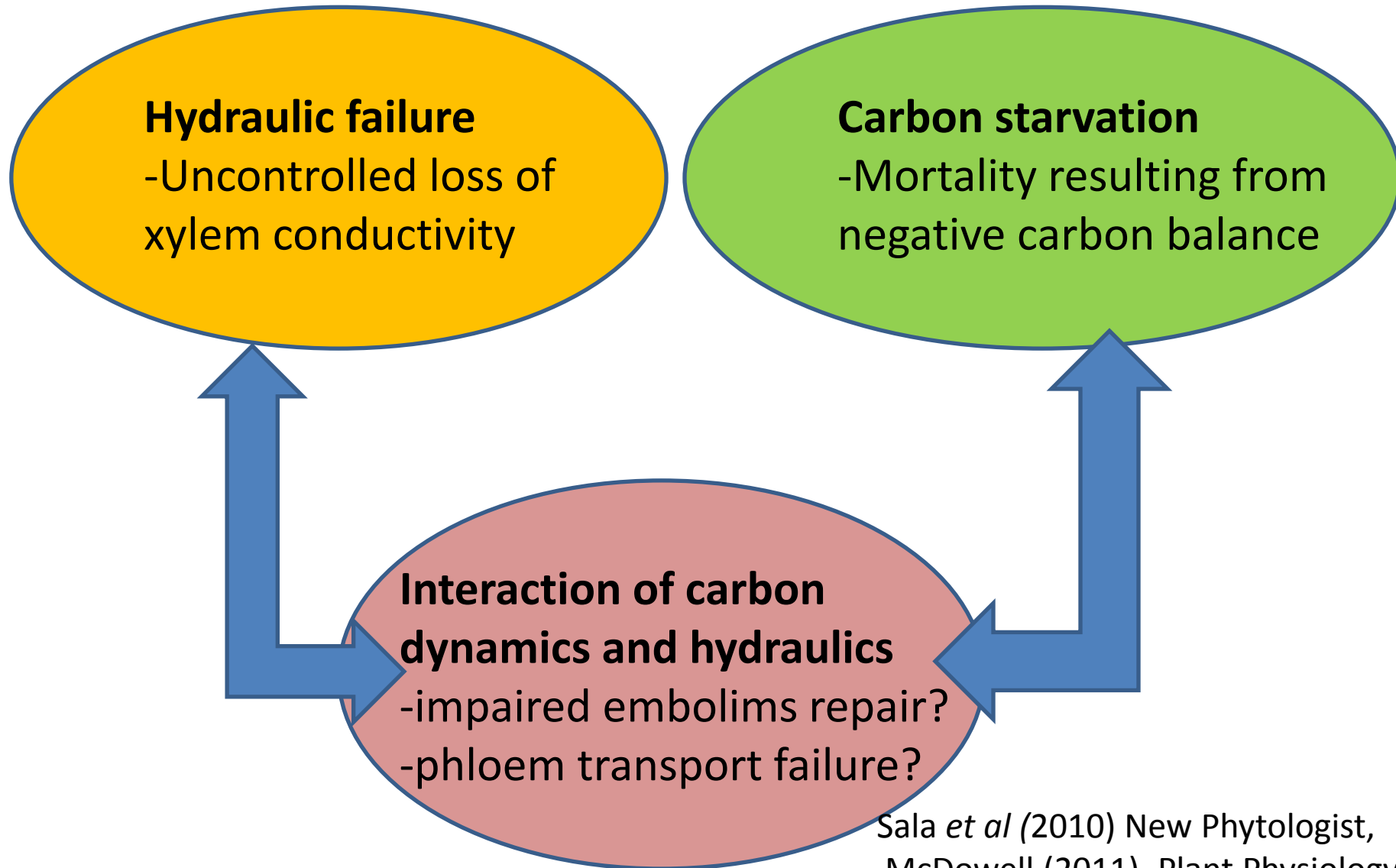
Phloem transport and drought

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Motivation: How do trees die during drought?

McDowell *et al* (2008) New Phytologist

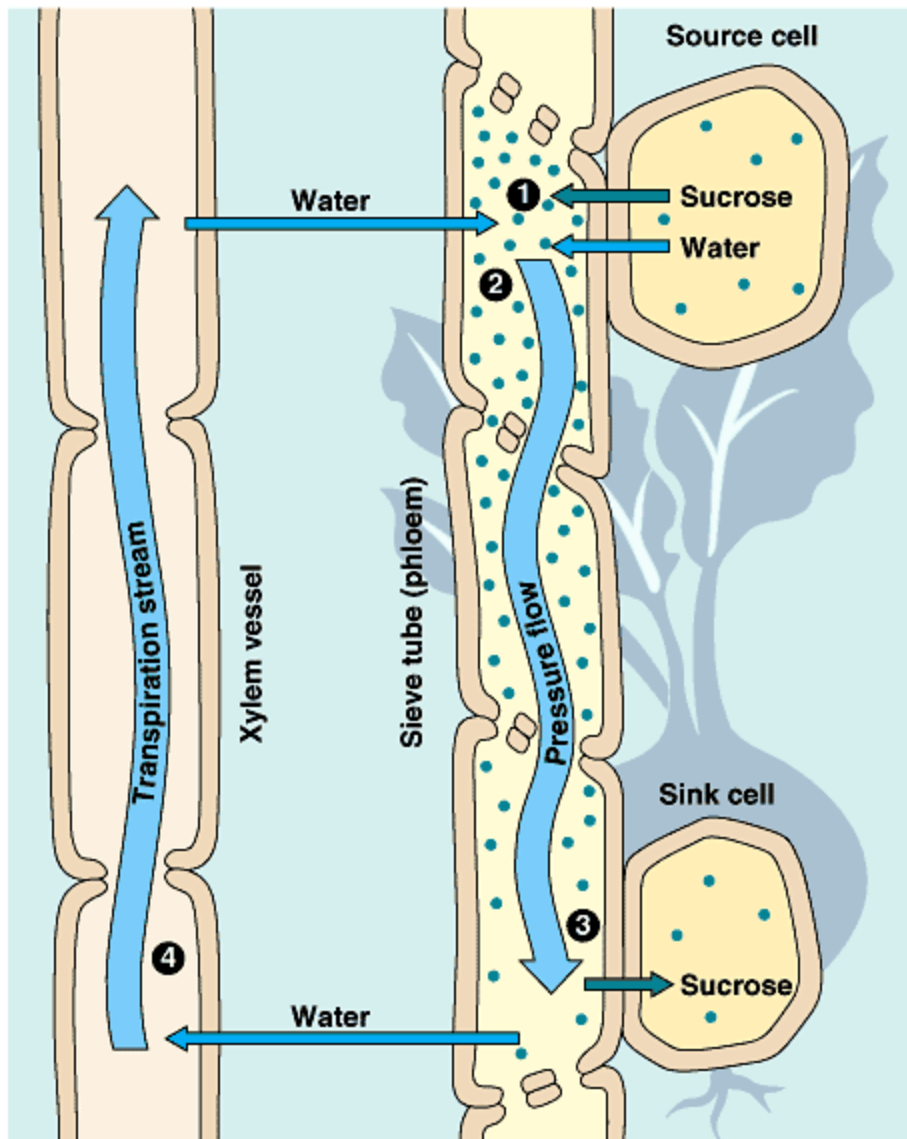


Sala *et al* (2010) New Phytologist,
McDowell (2011), Plant Physiology

Questions:

- How does drought affect phloem transport?
- What kind of a phloem could operate during drought?
- Does phloem failure occur during drought, and if so is it important for survival?

Classical view of phloem transport:



Semipermeable source
connected to a
semipermeable sink via a **non-**
permeable tube

Volume flow rate:

$$q = \frac{\pi r^4}{8L\eta} RT(c_{source} - c_{sink})$$

Munch, 1928; Thornley & Johnson 1990;
Minchin *et al* 1993

Increasing viscosity may
lead to...

Blockage of axial transport

What kind of a phloem could operate during drought:

Classical view

$$q = \frac{\pi r^4}{8L\eta} RT(c_{source} - c_{sink})$$

The larger the conduits, the higher the flux, even with high viscosity

If we assume independent sieve elements

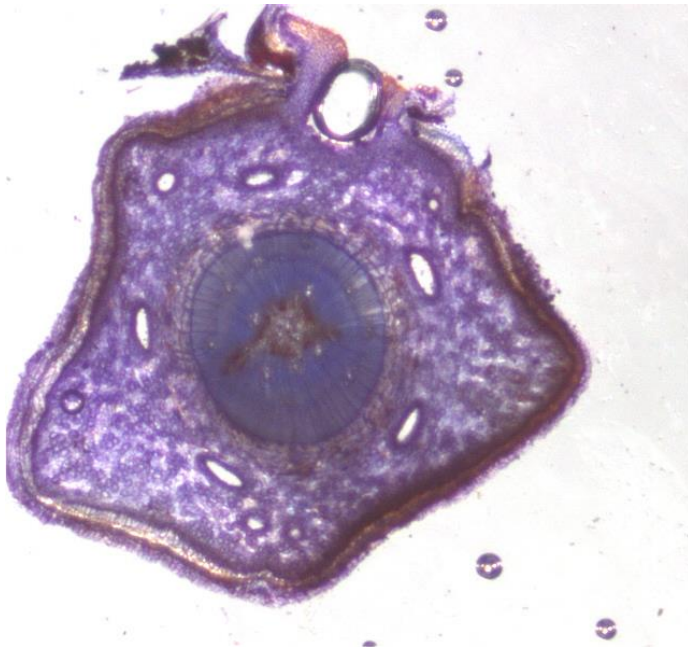
$$Q_{tot} = \sum_{i=1}^n q_i = \sum_{i=1}^n \frac{\pi r_i^4}{8L\eta_i} RT(c_{source} - c_{sink})_i = nq$$

More conduits = higher flux

Any support for this theory?

Pinon pine:

- closes stomata normally at -2.3 - -2.5 MPa
- Average $A_p/A_x = 0.82$



Juniper:

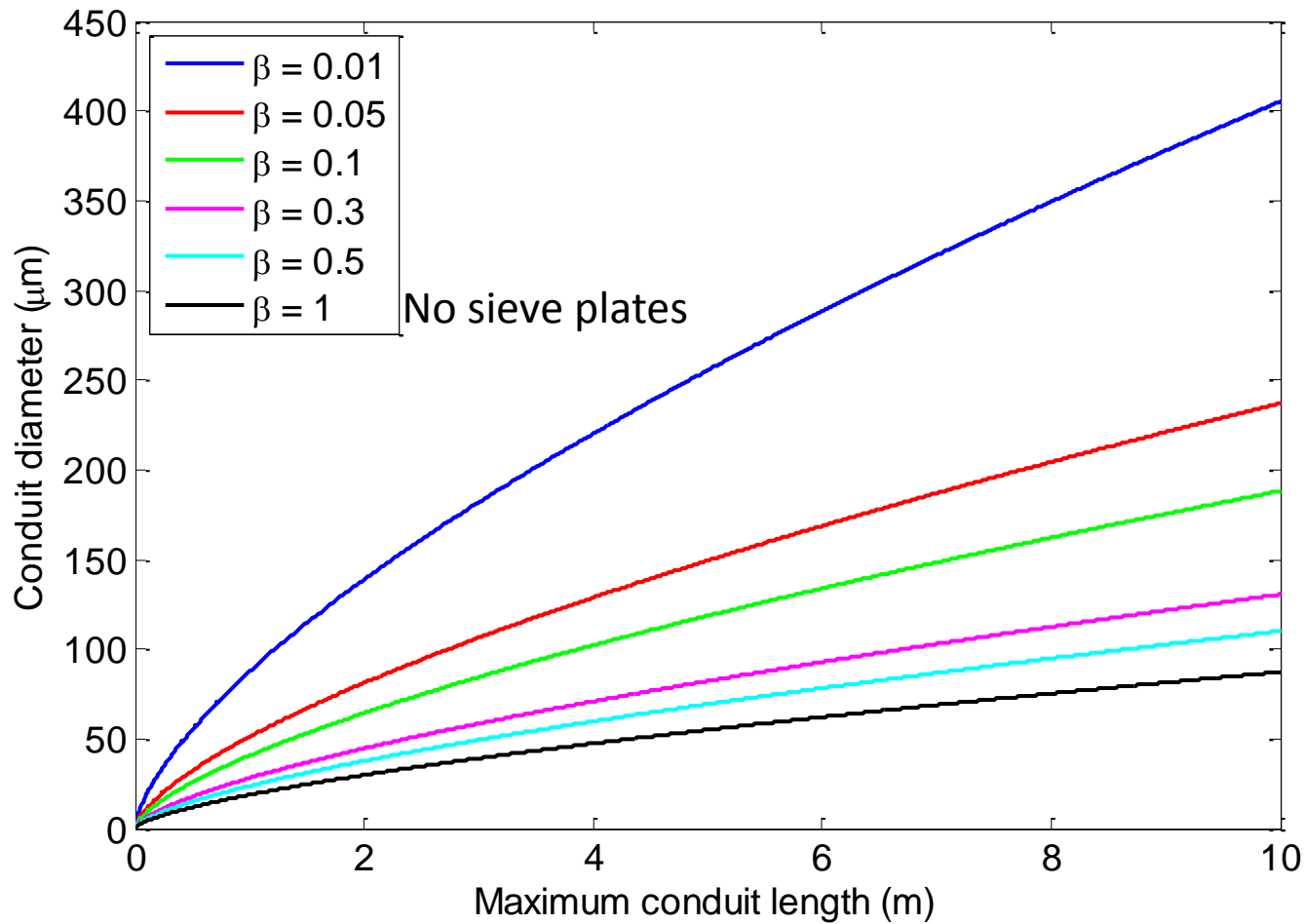
- closes stomata at -6 - -7MPa
- Average $A_p/A_x = 1.16$



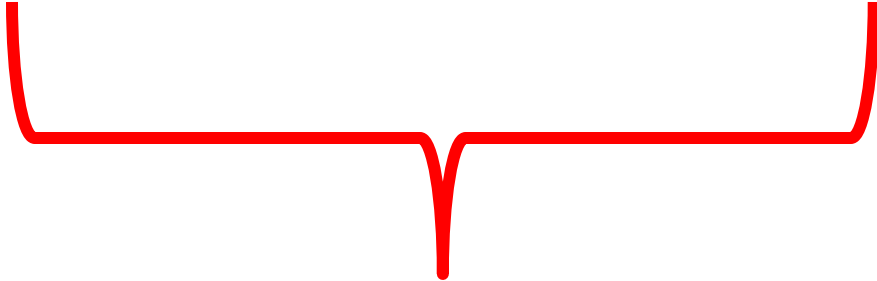
Is there a viscosity limit?

$$R = 2LL_p \frac{8\eta L}{\beta r^3} = \frac{\text{Axial resistance}}{\text{Radial resistance}}$$

Thompson & Holbrook 2003 PCE

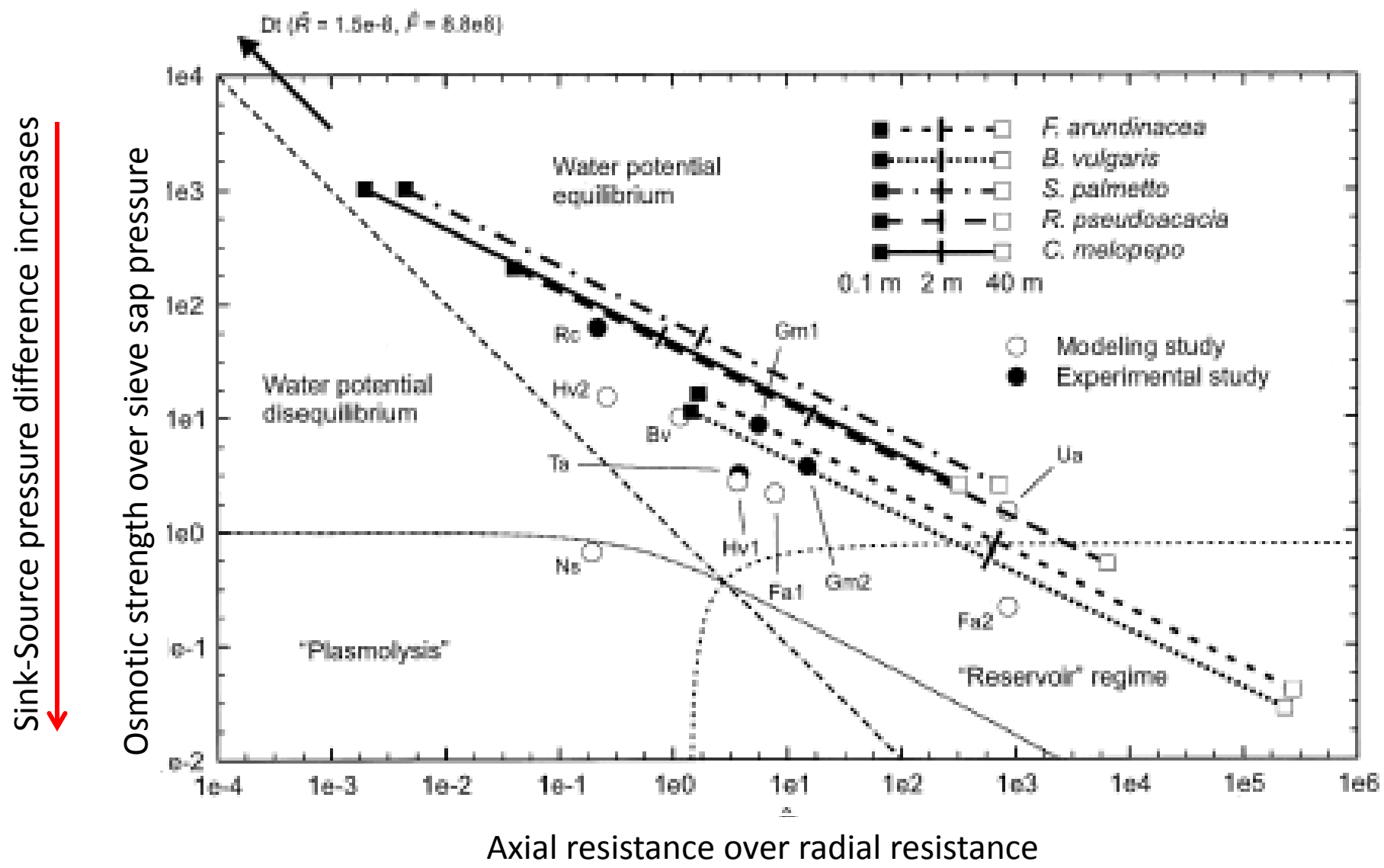


Does phloem transport cease during drought?

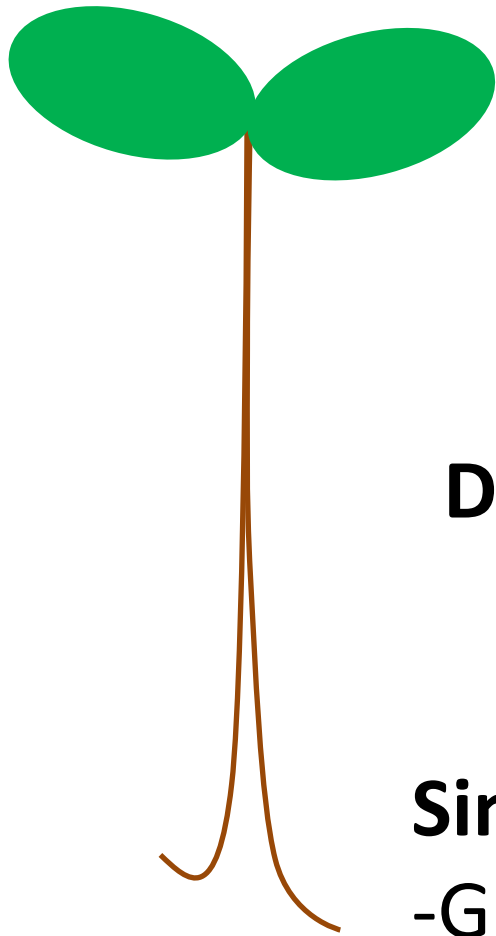
$$q = \frac{\pi r^4}{8L\eta} RT(c_{source} - c_{sink})$$


Plants can compensate for increasing resistance by increasing source –sink pressure difference

Does phloem transport cease during drought?



Does this matter at all?



Source:

-Stomatal closure → reduced productivity

Do we need transport?

Sink:

- Growth ceases
- Respiration decreases (or not?)

What have we observed? Experiment with pinon pine



Drought treatment:

-fast dying trees

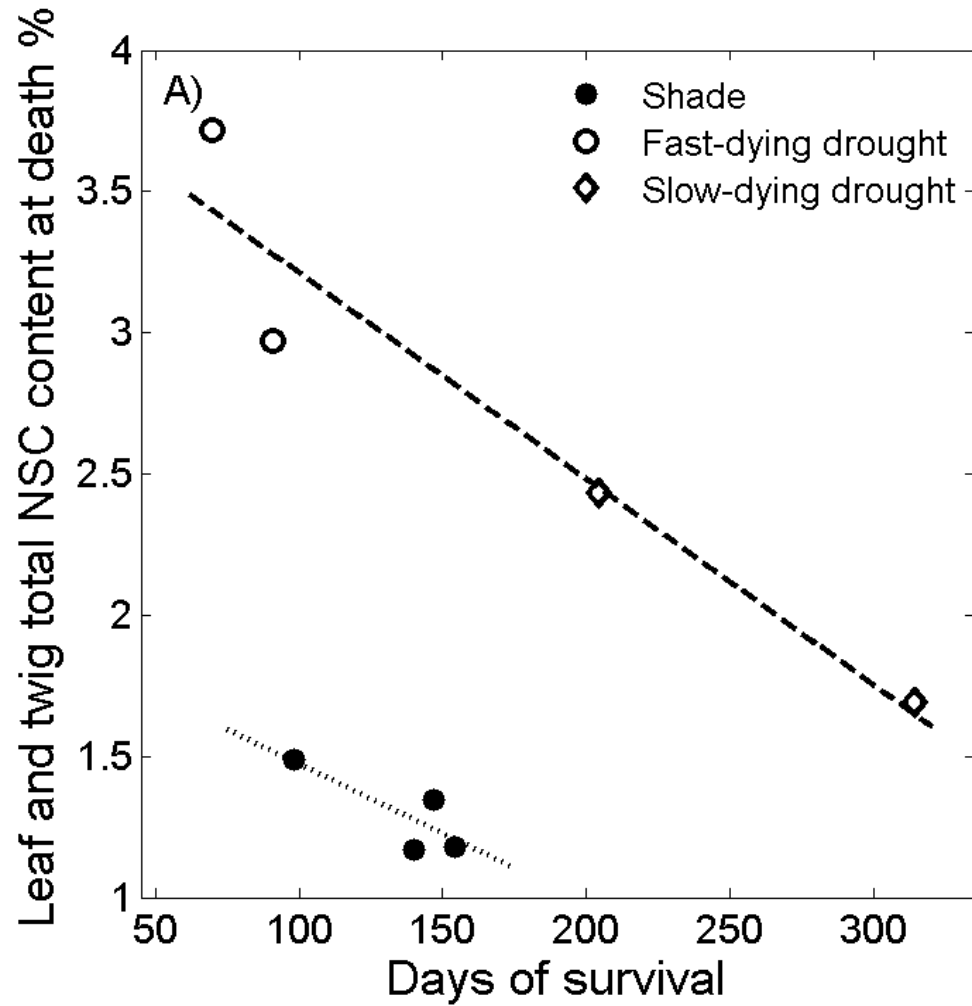


-slow-dying trees

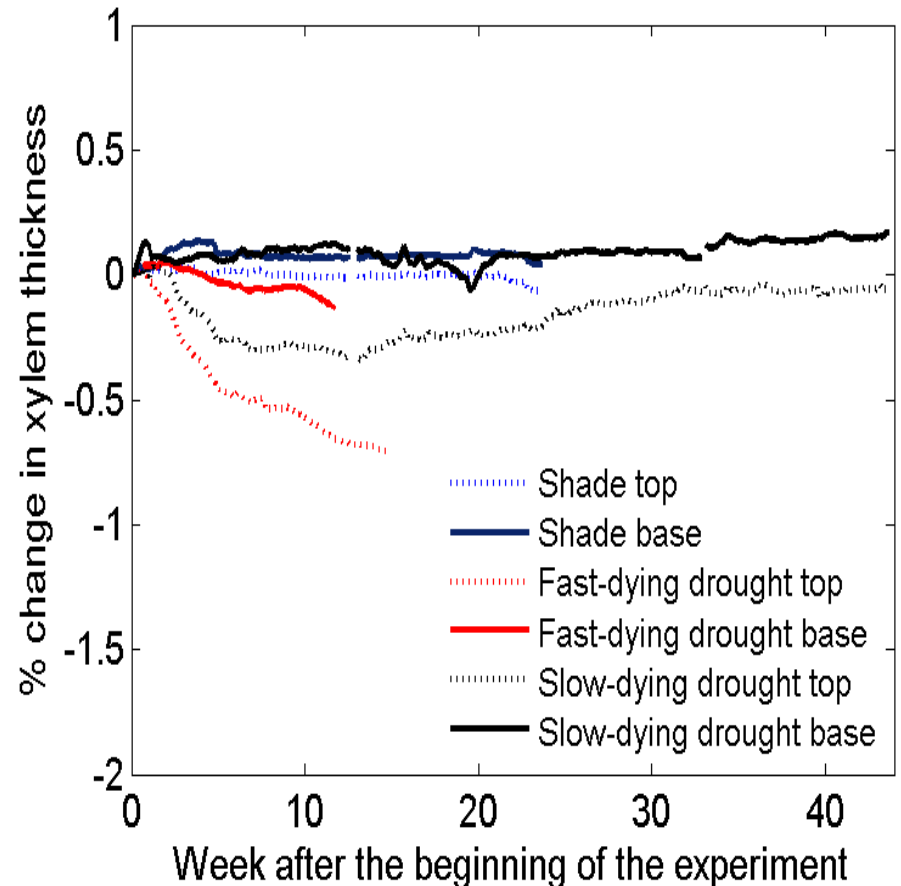
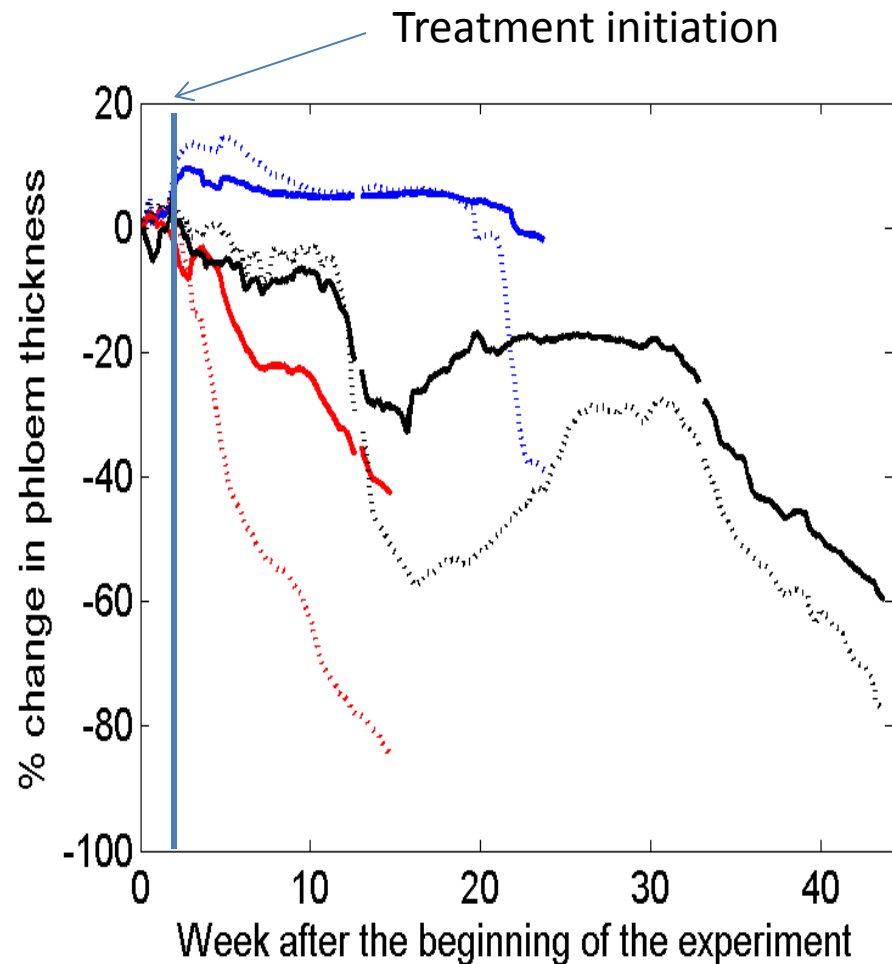


Shade treatment

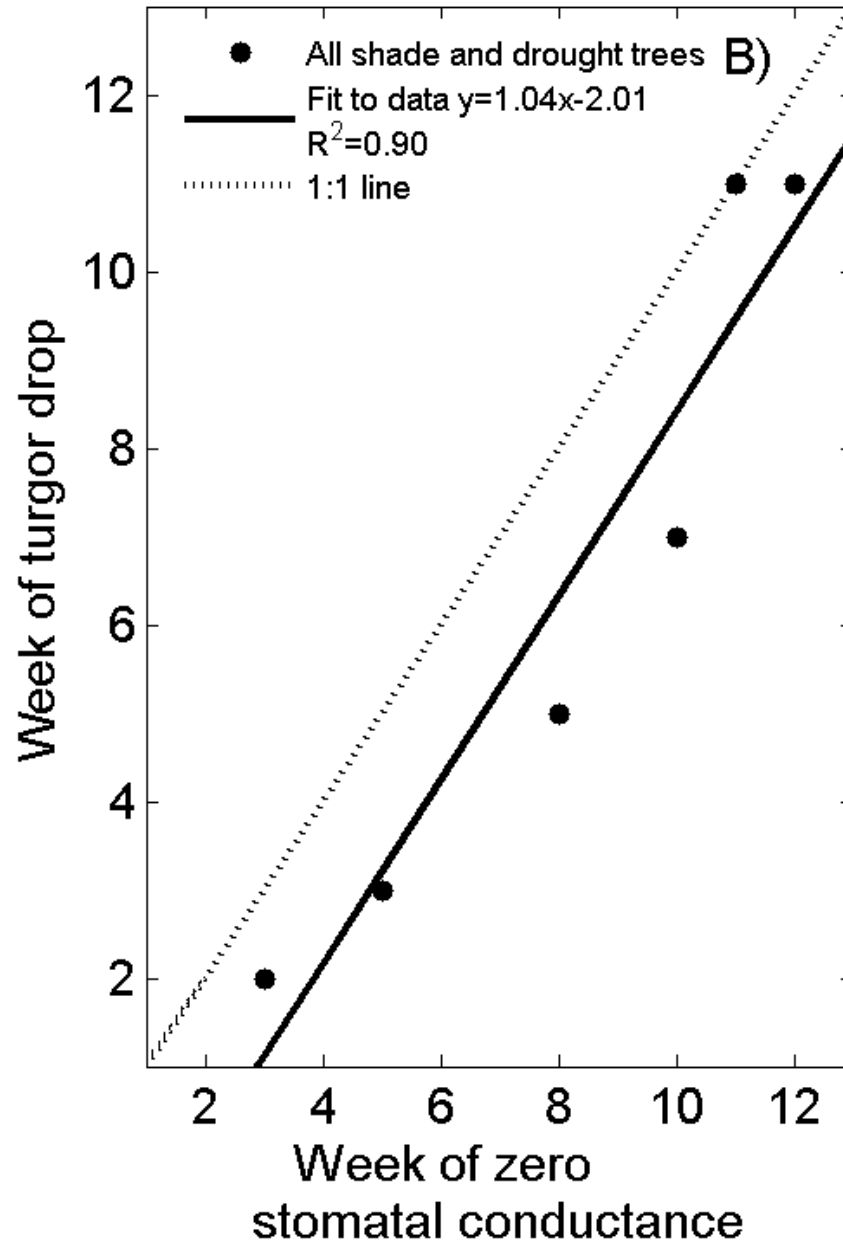
Access to carbohydrate stores affects survival time



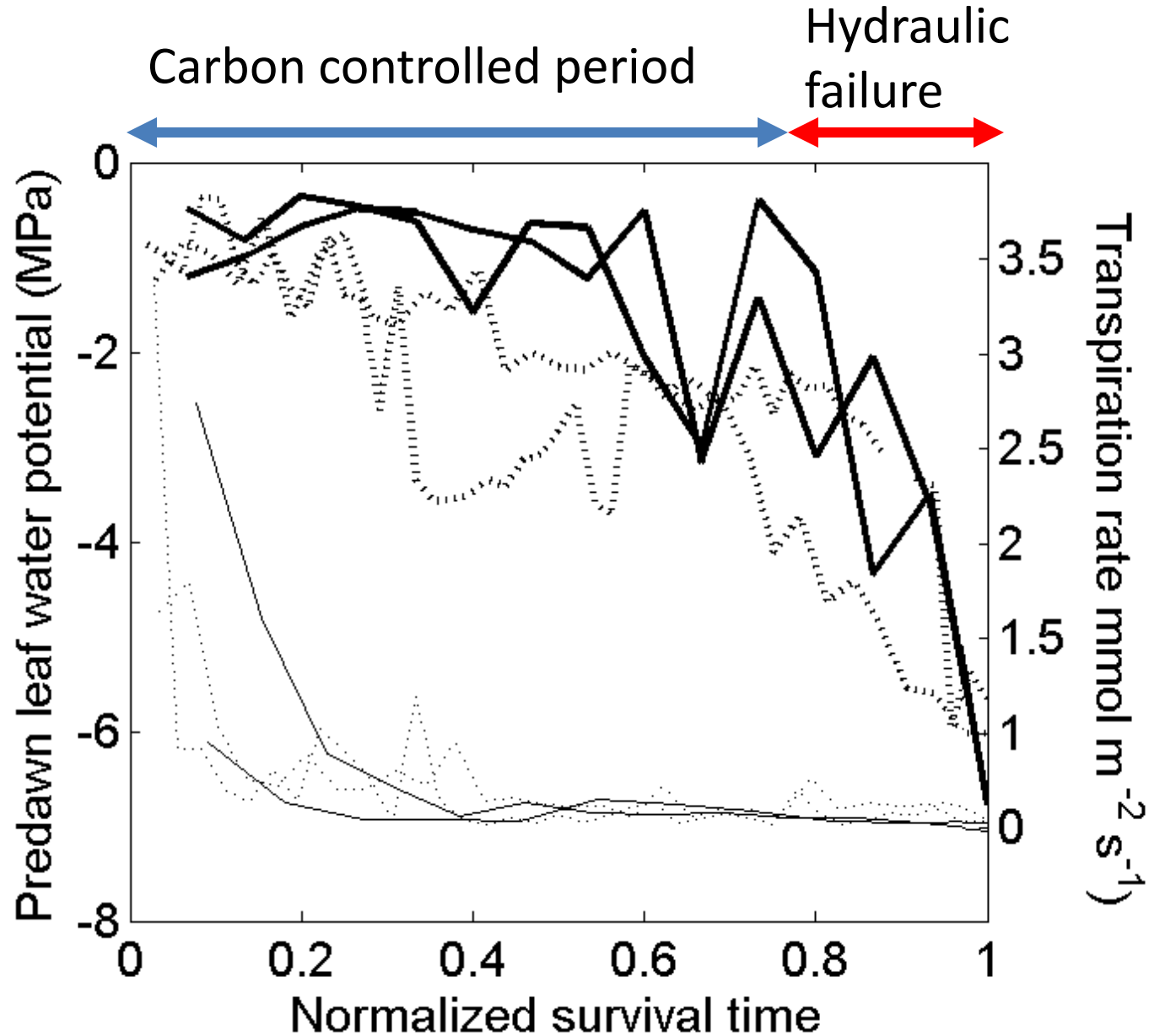
Phloem turgor collapses during drought



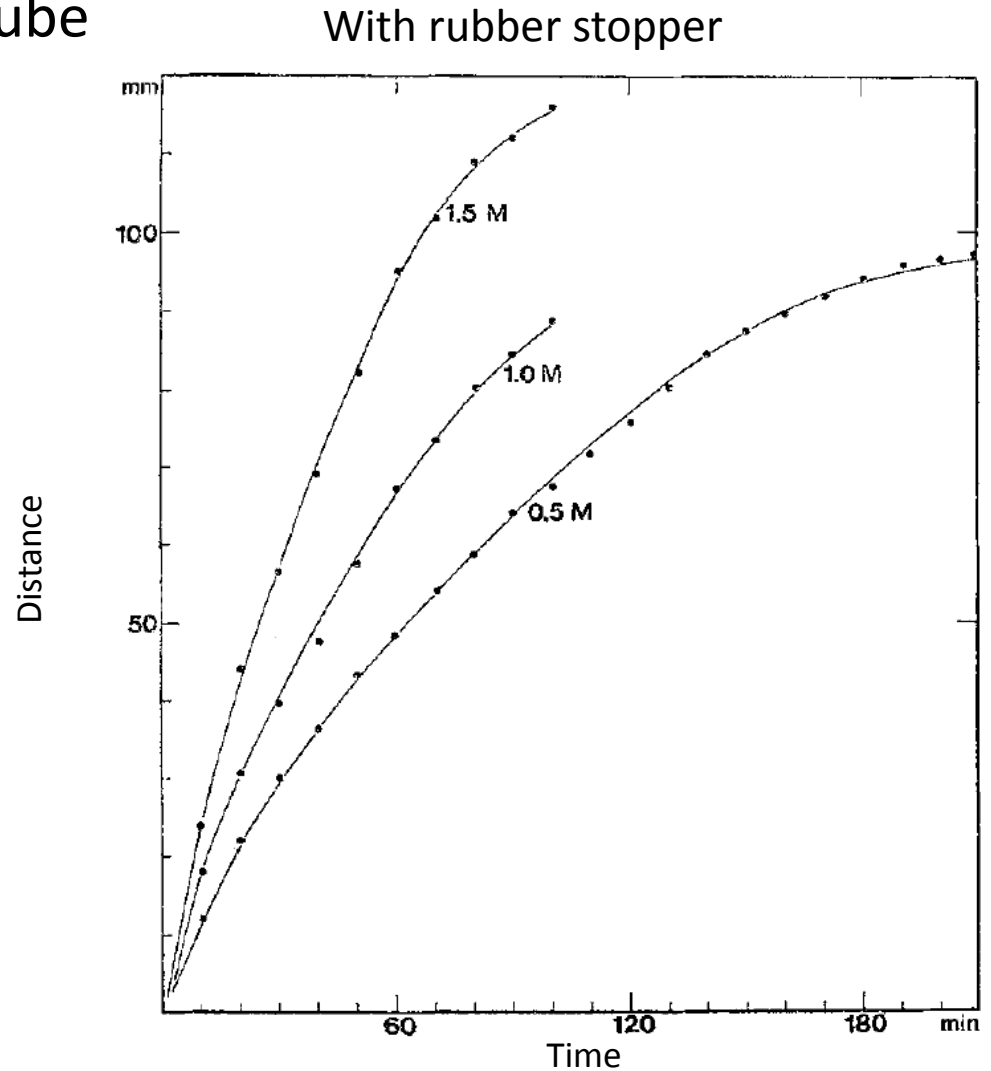
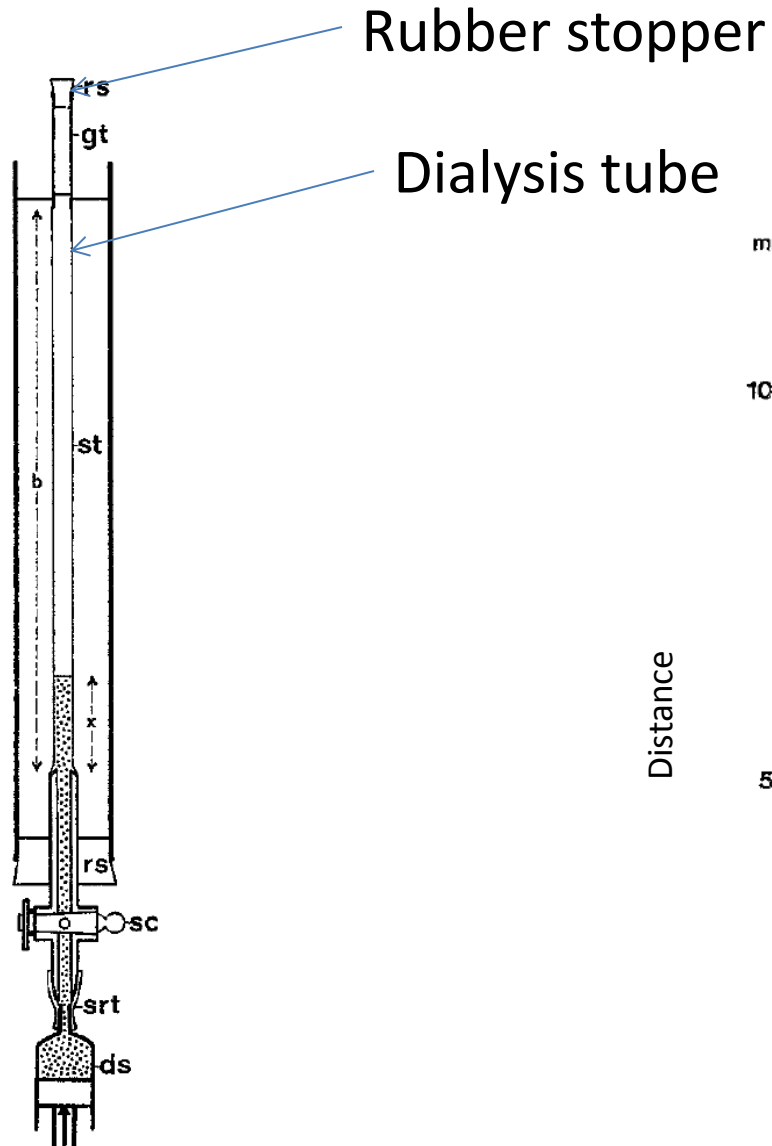
Turgor collapse precedes stomatal closure



Phloem turgor collapse determines survival time

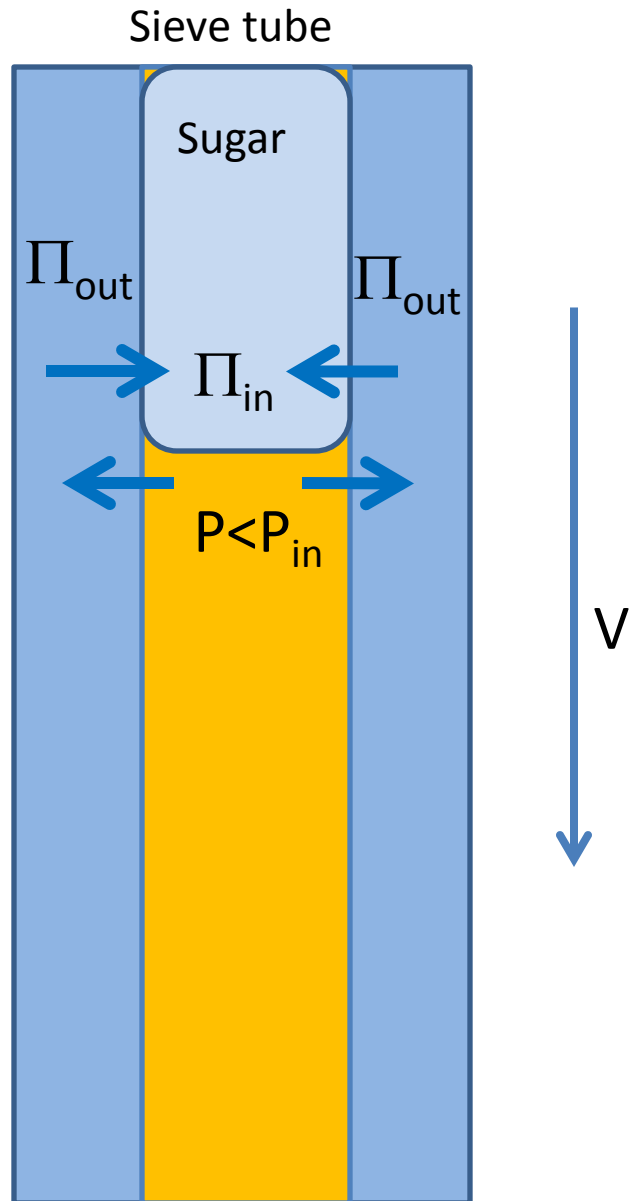


Semipermeability of the walls Eschrich *et al.* (1972) *Planta* 107:279-300



How does this work?

Eschrich *et al.* (1972) *Planta* 107:279-300



$$V \propto \Pi_{out} - \Pi_{in}$$

In the classical models:

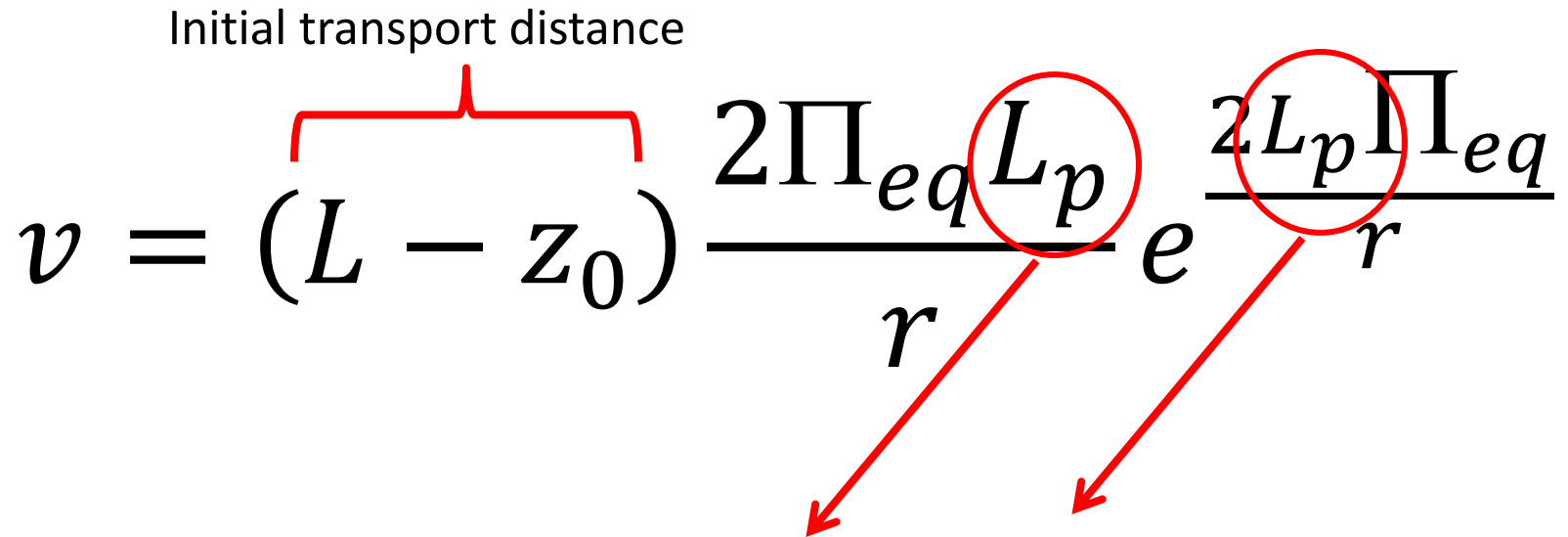
$$V \propto \frac{\partial P}{\partial z}$$

See also Knoblauch & Peters (2010) PCE

Permeability limits?

Eschrich *et al.* (1972) *Planta* 107:279-300

Initial transport distance

$$v = (L - z_0) \frac{2\Pi_{eq} L_p}{r} e^{\frac{2L_p \Pi_{eq}}{r}}$$


L_p goes to zero, v goes to zero

Note also that v increases with decreasing r

Conclusions:

How does drought affect phloem transport?

-Drought leads to phloem dysfunction, BUT the mechanism may be different than we thought

What kind of a phloem could operate during drought?

-It depends on what we believe about the transport mechanism. Semipermeability might be a key.

-Timing of phloem turgor collapse affects plant survival time

